thermoelectric pyrheliographs manufactured by Jules Richard in Paris.

The new Richard recording galvanometers (millivoltmeters) are, however, specially adapted for solarigraphs. By using coils with low resistance, approximately the same as that of the solarimetric piles, a marked increase in deflections was obtained. The sensitivity of the solarigraph is sufficient to get a deflection even with cloudy weather; characteristic variations are obtained on the diagrams, provided the thickness and transparency of the cloud changes.

In Figure 5 is shown a solarigraph record obtained on October 4, 1926, at the Solar Radiation Observatory of the U. S. Weather Bureau, American University, District of Columbia, where, through the courtesy of Professor Marvin, our solarigraph was calibrated. I am particularly indebted to Dr. H. H. Kimball, in charge of the Solar Observatory, and to his assistant, Mr. Irving F. Hand, for their kind help and very valuable suggestions during my stay at the observatory.

The record of October 4, 1926 (fig. 5); was obtained during a mostly clear day, although some clouds (visible between 12:30 and 1:30 p. m.) caused certain irregularities in the curve. Such a solarigram can be used for calculations, for instance, by planimetric methods, of the daily sums of solar and sky radiation on a horizontal surface.

Both direct-reading and recording solarimeters are made with two or more ranges, which permit the obtaining of greater deflections during cloudy or winter days with low sun. A very useful and important feature of the solarimeter is that it is able to give interesting records even on cloudy days, when the normal pyrheliometer gives no indication at all.

NOTES, ABSTRACTS, AND REVIEWS

WILLIS ISLAND METEOROLOGICAL STATION

A meteorogical station on an island so small and low and far to windward of large land masses that its climate is almost as purely marine as if the island were a ship is Willis Island in the south Pacific east of Australia. Willis Island lies 250 miles east of the north Queensland coast, approximately in latitude 16° S., longitude 15° W. Above ordinary seas it is less than 500 yards long and about 200 yards wide, and its summit is just under 30 feet above low water. Across it blows the southeast trade at a velocity that rarely is less than 5 m. p. h., and frequently is over 20 m. p. h. for long periods.

It is some six years since the Commonwealth Bureau of Meteorology established a station on the island. This was done largely to keep an eye on tropical cyclones approaching the coast of Australia. In addition to the usual surface observations, a series of pilot-balloon observations has made possible a preliminary analysis of free-air conditions in this trade-wind region. The following excerpts are adapted from a paper dealing with the seasons 1922–23 and 1923–24, by Dr. E. Kidson, entitled: "Observations from the Willis Island Meteorological Station," in volume 17 of the Report of the Australasian Association for the Advancement of Science, 1924 (the Government Printer, Adelaide, 1926).

To most people it is the winds of Willis Island that will be of greatest interest. Except for short breaks in the cyclone season, due either to passing cyclones or to the advent of the northwest monsoon, the southeast trade blows almost continuously, the mean direction being from southeast by east. In the six months November to April about 70 per cent of the winds are from between south and east, and in the winter months between 80 and 90 per cent. As far as the results go, they indicate that the wind velocity is greatest in the months when the pressure is rising, with a maximum in April, and least when the pressure is falling. The diurnal variation of the wind is especially interesting, since it can not be affected to any large extent by the land. * * * There is a maximum frequency of easterly winds in the hours just before sunrise. This is followed by a maximum for the east-southeasterlies in the three hours preceding noon. Thereafter the southerly component becomes more prominent, and south-easterly to southerly winds have their maximum frequency during the 16 hours to 18 hours period. In the northwesterly quadrant the winds tend to become more northerly in the forenoon hours and more westerly in the afternoon. * * *

The lowest velocity is recorded in the early afternoon, at about 14 hours or 15 hours. After sunset there is a fairly rapid increase to a maximum at about 22 hours to 23 hours.

The diurnal variation seems to consist chiefly, therefore, in the production of an easterly component in the morning and a westerly in the afternoon. The mean velocity is 15.7 miles per hour (7.1 meters per second). * * *

Pilot balloon ascents were made once daily during the seasons 1922–23 and 1923–24. Among the first points noted with regard to the ascents are the small change in direction with height and the low height at which a maximum velocity is reached. * * * It must be remembered that for the upper levels results are available for clear days and days of light wind only, and consequently they may not represent mean conditions. It is unlikely, however, that the impressions they give are very misleading. Above 1 km. the direction gradually becomes more variable, southerlies and westerlies being more frequent. Above 4 km. it would seem that southwesterlies prevail, while at still higher levels it is most probable that northwesterlies are the most frequent. At the high levels winds from the northeasterly quadrant are the least frequent.

The winds do not in every case veer in the lower levels from the surface direction. In fact, the ratio of the number that back to the number that veer between 50 m. and 450 m. is 1 to 1.8. This ratio was obtained in both seasons, and is the same for winds of all types. The reason for this constancy is not clear. The northwesterly winds veer to a greater extent than the south-easterly.

Such evidence as there is tends to show that in general the velocities begin to fall off before 1 km. is reached and continue to do so over the range covered by the balloon ascents. Strong winds are rare, the strongest gusts recorded on the surface being about 18 m/s (40 m. p. h.). Velocities greater than this were only rarely met with in the first kilometer above the surface, though 29 m/s (65 m. p. h.) was reached on one occasion. Were a cyclone to approach very near the island these speeds would, of course, be greatly exceeded.—*B. M. V.*

THE CAUSES OF GLACIATIONS

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In a review of Prof. A. P. Coleman's "Ice Ages: Recent and Ancient" (Macmillan, 1926), C. E. P. Brooks writes as follows (in *Nature*, London, August 28, 1926), touching the far-from-solved problem of the causes of glaciations:

* * * These phenomena offer a definite meteorological problem, which the author sets out clearly in words which are worth quoting:

"Under normal conditions the world has a relatively mild and equable climate with no permanent ice at low levels even in the polar regions.

"From time to time * * * there have been relatively short periods of cold accompanied by a great extension of mountain glaciers, and sometimes also by the formation of ice sheets at low levels. In the most severe visitation of the kind ice sheets invaded the Tropics on three or perhaps four continents.

"Ice ages are, in most cases, broken by interglacial periods of milder climate. Sometimes this occurs two or three or more times, indicating a comparatively rapid oscillation from cold to warm and warm to cold.

"All parts of the world have their temperature lowered during an ice age, the Tropics as well as the temperate and Arctic zones."

The author then turns to the consideration of causes, but gives only a rather mechanical discussion of the various theories of climatic change which have been put forward from time to time. Wegener's theory of continental drift is mentioned, but without enthusiasm. Elevation perhaps comes nearest to a solution, but fails to account for world-wide cooling. The conclusion is that no single cause suffices. "Some combination of astronomic, geologic, and atmospheric conditions seems to be necessary to produce such catastrophic events in the world's history."

The difficulty of the problem is increased by the apparently haphazard way in which glaciations have developed. Time and again the author comments on the paradox of field work, especially on Permo-Carboniferous tillites, beneath an almost vertical sun in a temperature suggestive of anything but ice. On the other hand, so far as is known at present, the Antarctic continent escaped glaciation until the close of the Mesozoic, though of course the great Antarctic ice sheet may hide traces of many older glaciers. The northeast of North America, where the Quaternary ice sheets reached lower latitudes than anywhere else, has suffered glaciation over and over again. In the upper Carboniferous this region bore glaciers which indeed pale into insignificance beside the contemporaneous ice sheets of the south, but would be sufficiently remarkable in any other period. The same region was ice-covered in the Devonian, the Ordovician, at the close of the Proterozoic, in the lower Huronian (a photograph shows the remarkable feature of a Huronian tillite smoothed and striated by a Pleistocene ice sheet), and perhaps at two horizons in the Archæan—seven or eight glaciations in the same or neighboring areas. Other regions which have suffered repeated glaciation are Alaska, South Africa, and southeast Australia, though South Africa was not glaciated during the Pleistocene.

It almost seems as if, given certain conditions, and especially a world-wide cooling, glaciers and even ice sheets can develop in any latitude, but have a preference for certain localities. From this point of view it may be only an accident that the two great ice sheets of the present day occur in high latitudes. Their formation is not entirely a matter of temperature, since we are faced by the idea that during most of geological time the polar regions were free of land ice even while lower latitudes were being glaciated. Apart from pole wandering, the only theory which throws any light on this anomaly is Paschinger's, not mentioned by Coleman, that glaciation depends on the relation between the zone of maximum snowfall and the snow line. It may be profitable to try to fit this theory to the facts before us.

As we go from the lowlands up the slopes of a mountain range, we find that the snowfall increases up to a certain level, above which it again decreases; this level depends mainly on the humidity and the temperature during the wettest season. Quite distinct, depending mainly on the summer temperature, is the snow line. If the snow line is above the zone of maximum snowfall, the glaciers will be small; if the snow line is the lower, the glaciers will be large, and with sufficient snowfall may descend to low levels. In the moist equatorial regions the two zones are close together, and a small depression of the snow line would produce a considerable extension of the glaciers.

It seems probable that glaciers or ice sheets must always *originate* on high ground, but for a glacier to develop into an ice sheet a large area of more or less level ground is required at a temperature low enough for the ice to spread out as a piedmont glacier. In high latitudes this land may be low, but in low latitudes it must be initially at a high level. Once the ice sheet has reached a certain size, however, it imports its own climate, and the initially high plateau may be depressed nearly to sea level without necessarily destroying the ice sheet. There are several reasons for this. One of the most important is that a snow surface reflects four-fifths of the solar radiation falling on it, and another is that a large ice sheet is naturally occupied by an anticyclone with outwardly directed winds. The relations between snow line and zone of maximum snowfall probably depend on conditions of storminess and vertical temperature gradient which are due to general causes; when these are favorable, glaciers will form which may develop into ice sheets in suitable localities, determined partly by configuration, which is independent of latitude, and partly by location relative to storm tracks and oceans. The latter proviso causes the repetition of glaciation in certain localities which are not necessarily the coldest parts of the globe. During the course of an ice age the most suitable location may change, which brings us back to Coleman's speculation that the Greenland ice sheet may represent the continuation of the eastward trend of glaciation in America, having commenced later than the American ice sheets and persisting after them.

The author has done good service by uniting in one volume a large mass of material which was formerly only available in scattered papers or, in the case of his own observations, had not previously been published. The volume maintains the high standard which we expect of the publishers; it is lavishly illustrated by photographs of great interest, and the only error which the reviewer has noticed is the name "Grygalski" on page 286.—*C. E. P. Brooks.*

THE CLIMATE OF NORTH-EAST LAND

In a paper in the *Geographical Journal* for September on the weather of North-East Land, Spitsbergen, during one month in the summer of 1924, Mr. K. S. Sandford has collected some evidence of value in relation to the problem of glacial anticyclones. In this relatively small but almost entirely ice-covered area he found no fixed anticyclone but a definite tendency toward the establishment of anticyclonic conditions with radial gravitational winds. This intermittent glacial anticyclone is blotted out by interference from outside the area but quickly reestablishes itself. Winds are markedly outflowing and lead to an augmentation of the bordering ice at the expense of the higher parts of the interior. On the other hand, interference from the outside is great and leads to melting of ice in the bordering zone and to a less extent in the interior. During the maintenance of anticyclonic conditions there is some indication of a pulsation, from calm to blizzard. Mr. Sandford believes that on New Friesland, on the mainland of Spitsbergen, there is a similar but modified system. Other parts of Spitsbergen have an insufficient ice covering for its development. Up to the present there are no winter observations available from North-East Land.—*Repr. from Nature (London), September 6, 1926.*

EXTENT OF ORCHARD HEATING IN SOUTHERN CALIFORNIA

The fruit-frost service of the Weather Bureau, in charge of Mr. Floyd D. Young, is compiling data on this subject, which when completed will form the first authoritative information with regard to it. The work is divided into eight districts, for each of which it is hoped to have complete data before the spring of 1927. In summarizing the work for the Redlands-San Bernardino district, Mr. A. W. Cook, of the Weather Bureau, writes as follows (*California Citrograph*, July, 1926):

> There are 29,691 acres of citrus trees in the entire Redlands-San Bernardino fruit-frost district, of which 5,789 acres, or 19.5 per cent, are equipped with heaters. The increase in acreage protected since the spring of 1925 is 2,977, or 51.4 per cent of the total. On the basis of fifty 9-gallon oil heaters to the acre, 2,483,550 gallons, or roughly 250 carloads, of oil are required for one filling of the heaters. The Redlands section alone requires about 187 carloads of oil for one filling.

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A ONE-MAN THEODOLITE

The August, 1926, issue of *Meteorologische Zeitschrift* contains a description, with illustration, of this device, which appears to be new in the field of aerology. The advantages of a one-man instrument for use on meteorological expeditions or other situation where reduction of personnel is essential are obvious.

In the new instrument the horizontal circle is retained in the form hitherto used, but the vertical circle is ingeniously incorporated within the field of vision of the telescope. The operator with his right eye not only follows the balloon with the aid of the cross hairs, but, aided by their lower vertical member as an index, he with the same eye reads the vertical angle upon an engraved glass circle. Set off at interpupillary distance to the left of the main eyepiece is the ocular of a microscope through which the observer looks, via a prism, upon the scale engraved on the horizontal circle.

Both horizontal and vertical circles are divided into whole degrees. Reading to tenths of a degree is accom-